# STAND STRUCTURE AND SUCCESSIONAL STATUS OF TWO SPRUCE-FIR FORESTS IN SOUTHERN UTAH

Donald P. Hanley,
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## ABSTRACT

Knowledge of the age-class distribution in the spruce-fir forests on the plateaus of southern Utah is necessary to prescribe silvicultural systems compatible with the ecological requirements of the species. Engelmann spruce, Picea engelmannii (Parry); subalpine fir, Abies lasiocarpa (Hook.) Nutt.; and quaking aspen, Populus tremuloides (Michx.), constitute the majority of the stands found on these high-elevation sites. Random samples of ages and diameters by species were analyzed from two stands on adjacent plateaus. Both stands are uneven-aged. Engelmann spruce, the primary species, is predominantly all-aged; subalpine fir is uneven-aged, but not all-aged; and aspen is even-aged. This age-class structure suggests the need for testing an uneven-aged silvicultural system in the management of these forests.

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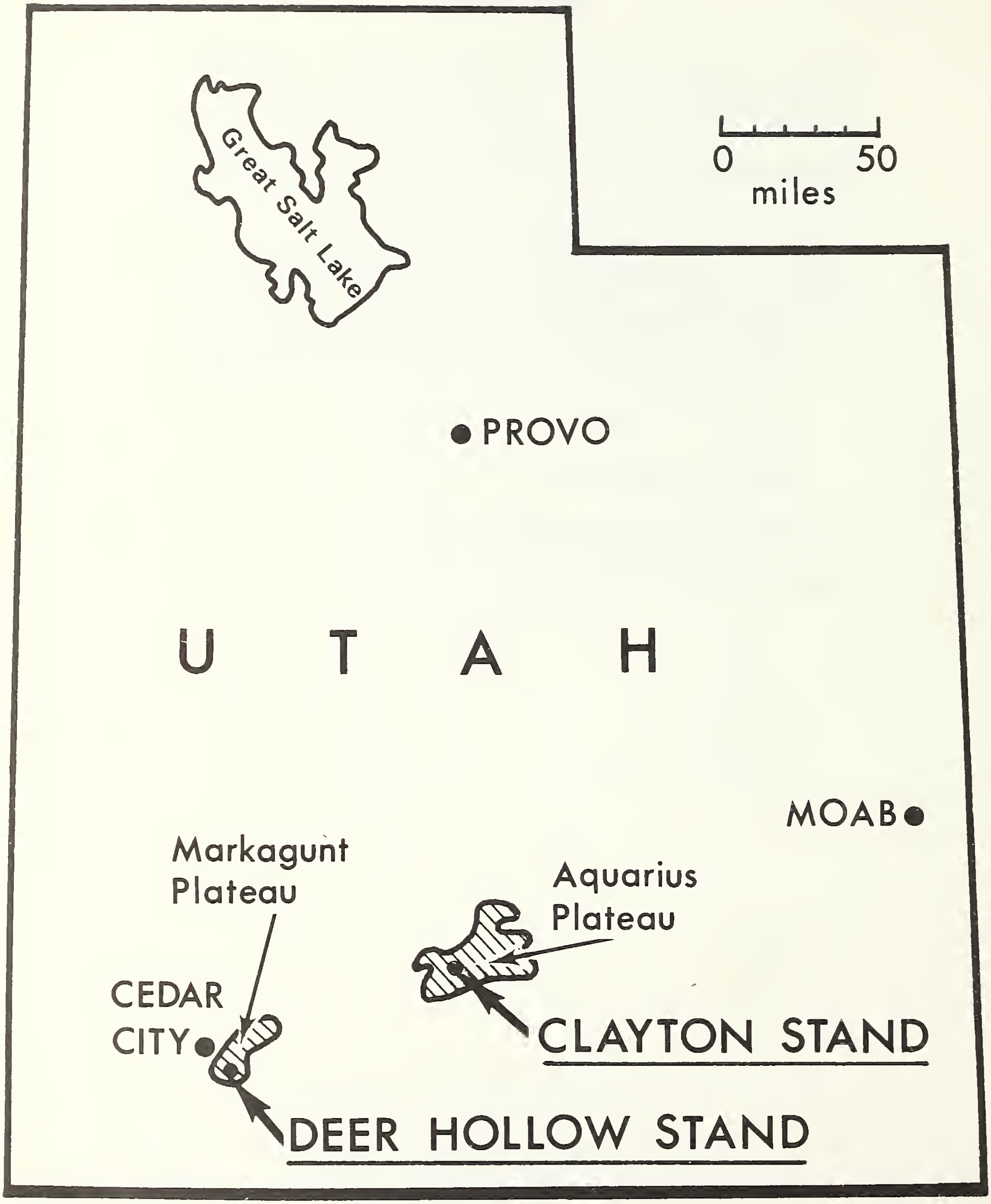


*Figure 1.--Clayton stand and Deer Hollow stand study area locations.*

# INTRODUCTION

Engelmann spruce, *Picea engelmannii* (Parry), and subalpine fir, *Abies lasiocarpa* (Hook.) Nutt., forests cover vast areas of the subalpine zone in the Rocky Mountains of the western United States and Canada. Both species grow in a cold, humid climate, characterized by cool summers, very cold winters, and heavy snowfall (Sudworth 1916). Although these high-elevation forests usually abut the timberline, they are also found in favorable environments at lower elevations. A review of past literature reveals great differences in the biotic and abiotic components of the spruce-fir type as one traverses from north to south along the range of the species (Roe and others 1970).

Stand structure apparently varies similarly throughout the type, with researchers reporting both even-aged and uneven-aged conditions. Bloomberg (1950) and Smith (1954) reported broadly even-aged structure in the spruce-fir forests of Alberta and British Columbia, while Day (1972) reported irregular to uneven-aged stands in southwestern Alberta where fire is infrequent. Hornibrook (1942), Miller (1970), and Alexander (1971) reported that the spruce-fir forests in Colorado are composed of even-aged stories intermingled on the same site. In recent publications, Alexander (1974) and Landis (1974) reported uneven-aged "multistoried" stands in Colorado. Mielke (1950) and Pfister (1972), through analysis of stump ages and diameter distributions, concluded that spruce-fir forests of southern Utah appear to be uneven-aged. Thus, it seems that age-class structure of spruce-fir forests depends upon the specific location and its environmental conditions.

Variable spruce-fir age-class structures have strong ecological and silvicultural implications that may help explain prompt or delayed regeneration throughout these forests. In general, the spruce-fir forests of the Rocky Mountains on lower elevation, northern latitude sites have been the easiest to regenerate and forests on the higher elevation, southern latitude sites, the most difficult to regenerate (Roe and Schmidt 1964). Persistent difficulties in establishing natural regeneration with even-aged clearcutting methods on spruce-fir sites in southern Utah raised an important question: Are the silvicultural systems being employed compatible with natural stand succession? This study, conducted on the Aquarius and Markagunt Plateaus (fig. 1), is aimed at determining the stand structure and natural successional development in the high-elevation spruce-fir forests of southern Utah. This paper suggests silvicultural systems most compatible with the natural establishment and development requirements of these important forests.

# STUDY AREA DESCRIPTIONS

Two high plateaus, with stands typical of the spruce-fir forests in southern Utah, were selected for this study. The Clayton stand on the Aquarius plateau and the Deer Hollow stand on the Markagunt plateau provided the sample base. These two stands are also the location of detailed spruce regeneration studies.[1] Thunderstorms and orographic lifting are the major precipitation sources throughout the short growing season, resulting in high-intensity storms almost daily (Farmer and Fletcher 1971). Snow accumulates at depths up to 12 feet, with some snow remaining in microsites well into June.

The Clayton stand (fig. 2) located in the center of the Aquarius Plateau, (200 air miles south of the Great Salt Lake) at 10,300 feet elevation is felt to be representative of the *Abies lasiocarpa/Ribes montigenum* habitat type (*Ribes* phase) (Pfister 1972). Approximately one-half of the subalpine forests of Utah are composed of this habitat type (Pfister 1972). Soils are a gravelly loam derived from andesite parent material (Pfister 1972).

The Deer Hollow stand, located on the southwestern edge of the Markagunt Plateau at 9,300 feet elevation, is approximately 70 air miles southwest of the Clayton stand. Deer Hollow represents a warmer climate than the other stand, as indicated by the *Abies lasiocarpa/Berberis repens* habitat type (*Ribes* phase) (Pfister 1972). Soils are a stony clay loam derived from Wasatch limestone (Pfister 1972).

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[1] Pfister, Robert D., and Donald P. Hanley. Intermt. For. and Range Exp. Stn., Missoula, Mont. (Manuscript in preparation.)

*Figure 2.--Clayton spruce-fir forest stand, located on the Aquarius Plateau in southern Utah.*

# METHODS

Ten sample plots, consisting of three concentric circular subplots of 1/100, 1/20, and 1/10 acre, were randomly selected at both Clayton and Deer Hollow (Hanley 1973). Tree sampling was based on diameter class (at 1 foot above ground level). The smallest individuals were sampled in the smallest subplot, and the intermediate and largest trees were sampled in the larger subplots, as follows:

| *Tree size classes* | *Spruce* | *Fir* | *Aspen and others* |
|---|---|---|---|
| 1-ft ht., 2-in. diam. | 1/20 | 1/100 | 1/20 |
| 2 to 6-in. diam. | 1/20 | 1/20 | 1/20 |
| 6 to 10-in. diam. | 1/20 | 1/10 | 1/10 |
| 10+-in. diam. | 1/20 | 1/10 | 1/10 |

All trees 2 inches in diameter and larger were aged at 1 foot in height by extracting increment cores. Disks were cut at ground line and at 1 foot above ground line from trees that were less than 2 inches in diameter for age analyses. Modal age values required to achieve 1 foot in height were derived from the disks of the small trees and were added to the increment core values of the larger trees to arrive at a total tree age. Modal age values were used because median or mean values would have adversely weighted the results toward very suppressed individuals which likely do not represent initial growth rates for larger trees now present. Modal age values had an average standard deviation of 9 years and are as follows:

| | *Clayton stand* | *Deer Hollow stand* |
|---|---|---|
| Engelmann spruce | 9 | 10 |
| Subalpine fir | 8 | 10 |

Heart rot incidence was determined for all trees measured. Site index was based on spruce site curves (Alexander 1967) and determined by selecting three dominant crown position spruce trees at each plot.

Uneven-aged stand, even-aged stand, and all-aged stand are commonly used for describing the age-class structure of forest stands. For clarity, we have adopted the definitions as stated by the Society of American Foresters (1971) as follows:

| | |
|---|---|
| All-aged | A forest stand that contains trees of all or almost all age-classes, including those of exploitation age. |
| Even-aged | A forest stand composed of trees having no or relatively small differences in age. By convention, the maximum difference admissible is generally 10 to 20 years, though with rotations of less than or equal to 100 years, differences up to 30 percent of the rotation age may be admissible. |
| Uneven-aged | A forest stand composed of intermingling trees that differ markedly in age. By convention, a minimum range of 10 to 20 years is generally accepted, though with rotations of less than or equal to 100 years, 25 percent of the rotation age may be the minimum, in the United States. |

The following chart may help clarify the definitions as used in the United States:

| *Conditions* | *25% age groups of rotation age* | | | |
|---|---|---|---|---|
| Even-aged | X | | | |
| Uneven-aged (1) | X | X | | |
| Uneven-aged (2) | X | X | X | |
| Uneven-aged (3) (All-aged) | X | X | X | X |
| | *Establishment age* → | | | *Rotation age* |

An even-aged stand contains trees of one age group falling within 25 percent of the rotation length. An uneven-aged stand contains trees which fall in 2, 3, or 4 groups, each composed of 25 percent of the length of rotation. A theoretical all-aged stand is the ultimate uneven-aged condition.

# RESULTS AND DISCUSSION

## Diameter Distributions

Diameter distributions of spruce and fir were similar for both the Clayton and Deer Hollow stands (fig. 3 and 4). Both stands had large numbers of trees under 4 inches in diameter. The stand diameter distribution and a normal assumption of a diameter-age correlation (Hanley 1973) gives the stand the appearance of uneven-aged structure with both spruce and fir contributing to this condition. Aspen's *Populus tremuloides* (Michx.) diameter distribution curve, particularly at the Clayton site, approximated a normal probability curve--an even-aged distribution. Although evaluations of stand structure are often based only on diameter distributions (Smith 1962), a more precise evaluation is possible with actual age. The following analyses of tree ages found in these stands were used to confirm or reject the first impressions obtained from diameter distributions.

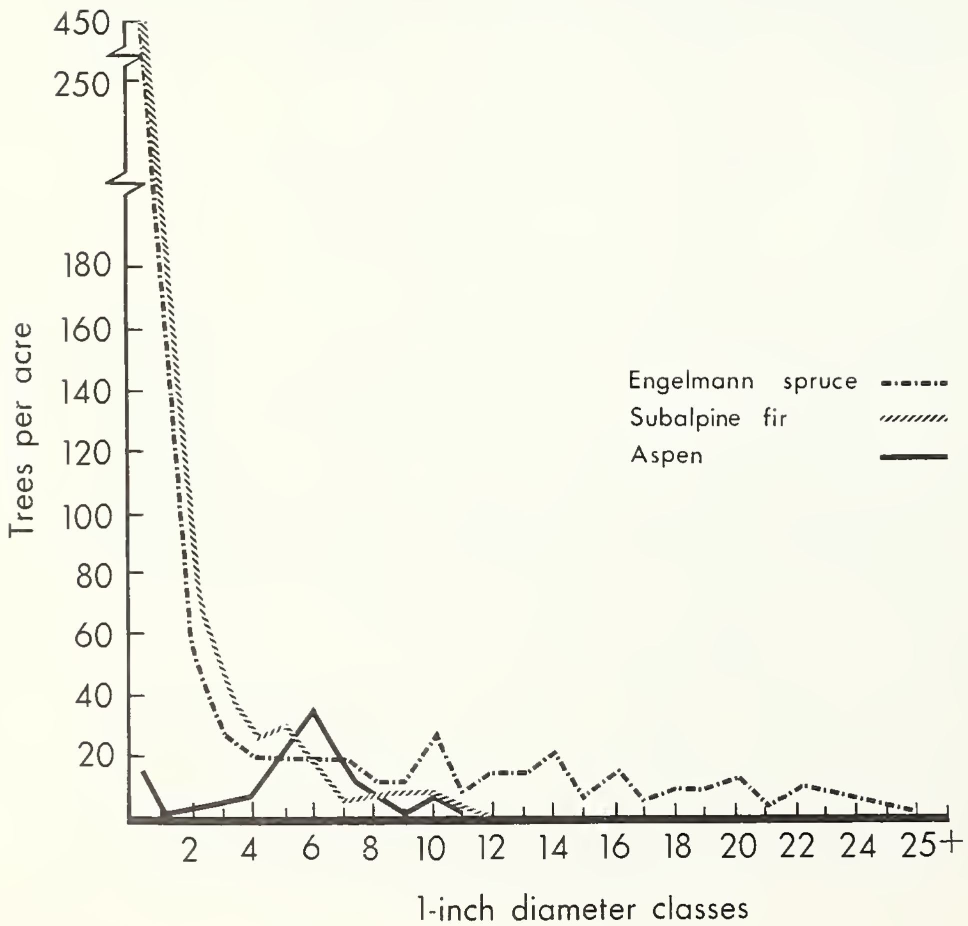
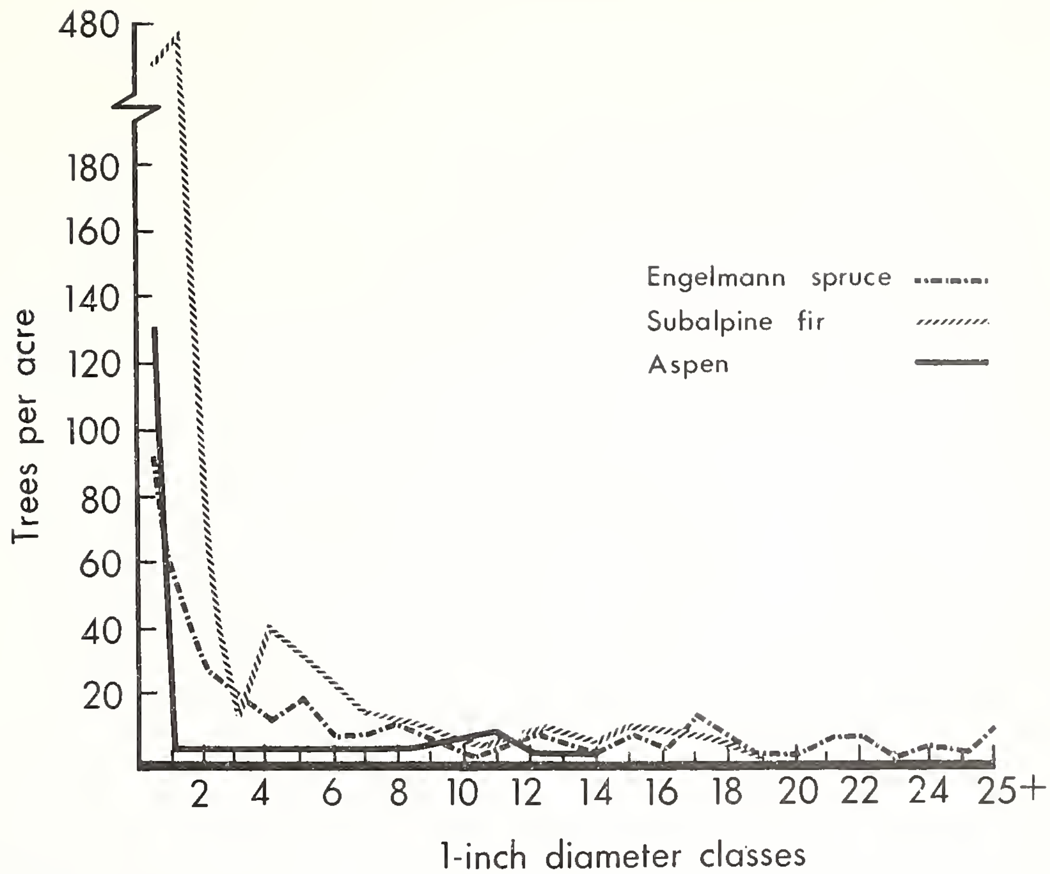



*Figure 3.--Clayton stand diameter distribution.*

Figure 4.--Deer Hollow stand diameter distribution.




## Age-Class Distributions

Age-class structure is a relative attribute of the stand because even-aged structure and all-aged structure are the theoretical endpoints to man's classification system. Thus, the determination of age-class structure is a matter of interpretation, combining the knowledge of the age distribution and successional trends acting on the site. The structures discussed here follow the qualitative definitions presented in the introduction.

*Clayton Stand*

Spruce ages at Clayton were distributed along a decreasing function curve characteristic of all-aged structure (fig. 5). Because of waves of spruce reproduction established about 50 and 130 years ago, this stand was not perfectly regular. Reproduction waves are not incompatible with the all-aged concept because they are normal attributes of a dynamic system (Jones 1945; Alexander 1958). However, the waves were not large enough in the Clayton stand to constitute a storied forest appearance--no canopy stratification was evident.

Subalpine fir in the Clayton stand was uneven-aged, but not all-aged. Abundance of trees in the 30-, 40-, and 50-year age-classes indicated prolific reproduction during these periods. For example, Dixon (1935) and Mielke (1950) reported an Engelmann spruce beetle *Dendroctonus engelmannii* (Hopk.) epidemic during the 1930 decade that possibly altered the spruce canopy enough to favor subalpine fir reproduction. Subalpine fir reproduction by layering was probably also abundant. Additionally, the long "tail" of the curve (70 to 160 years) indicated that fir was able to maintain itself under the spruce canopy, expressing uneven-aged characteristics.

Because of the prevalence of heart rot, it was impossible to age aspen for a large proportion of the sample. However, clones appeared to be generally from 40 to 70 years in age. Although clones varied in age, most trees within each clone appeared to be the same age. The even-aged clones were intermingled with the uneven-aged conifer stand.

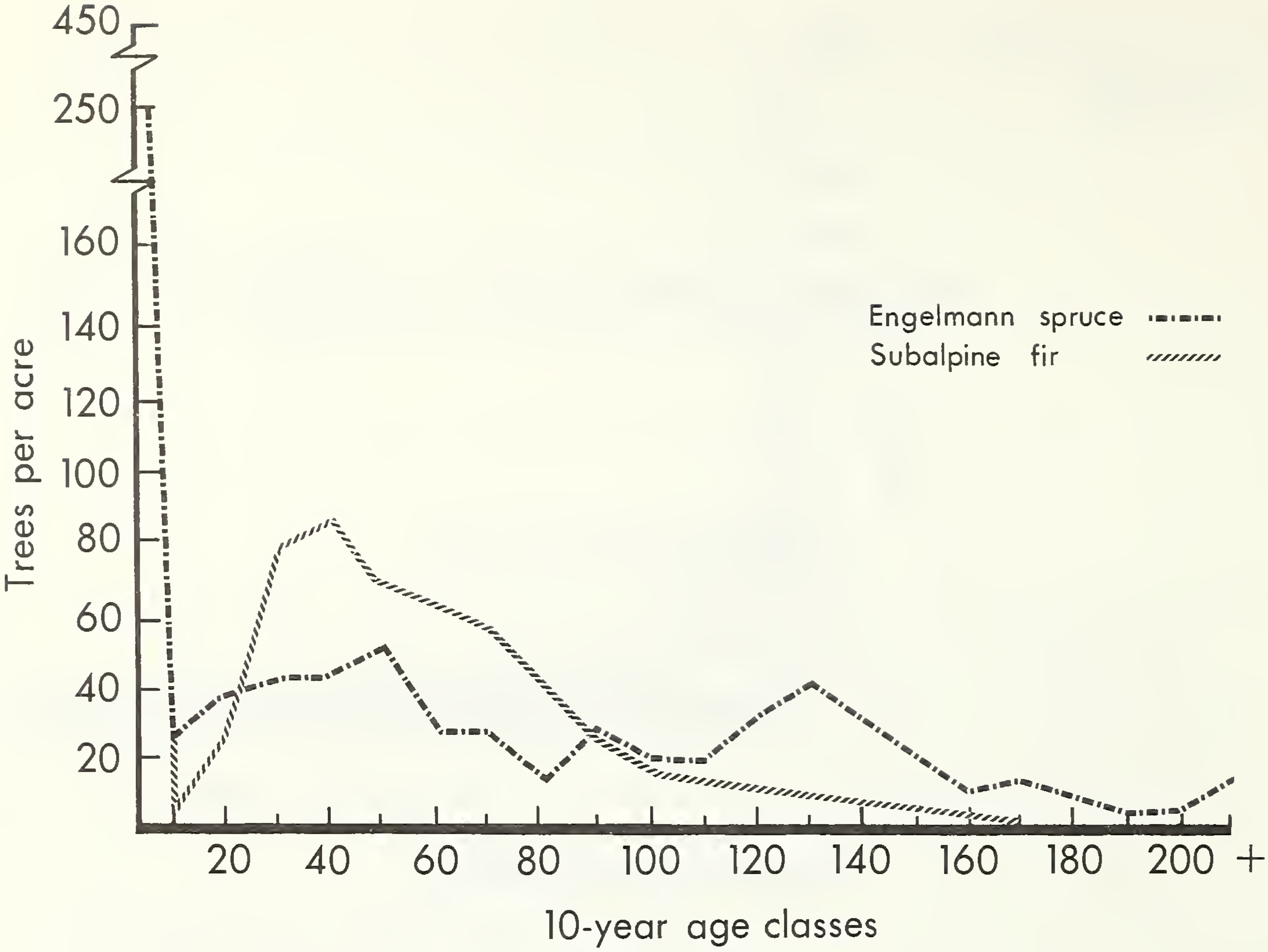



*Figure 5.--Clayton stand age-class distribution, 1972.*

*Deer Hollow Stand*

The Deer Hollow stand followed much the same pattern as the Clayton stand, exhibiting an uneven-aged distribution (fig. 6). Spruce was distinctly all-aged, even though a few of the age classes were poorly represented, resulting in an irregular condition. Subalpine fir exhibited uneven-aged characteristics, with age classes of 20 to 80 well represented. Large variations in the age-distribution graph indicated that fir reproduced in waves under favorable conditions, supplementing uniform and sometimes irregular establishments at other times.

Very few seedlings were sampled in the 10-year age-class (early 1960's) at either Clayton or Deer Hollow (fig. 5 and 6). We cannot pinpoint the exact reason for the lack of reproduction during this time period. However, lack of both spruce and fir reproduction *could* have been caused by unfavorable weather conditions resulting in frost kill, frost heaving, rapid soil surface drying, and soil movement both in the open and under the existing canopy.[2] Engelmann spruce vigor could have been reduced at the Clayton stand by mealy bug *Puto sandini* (Washburn 1965), resulting in poor spruce seed crops. This, coupled with high populations of seed-eating rodents[2] could have contributed to the poor reproduction during this period.

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[2]Op. cit.

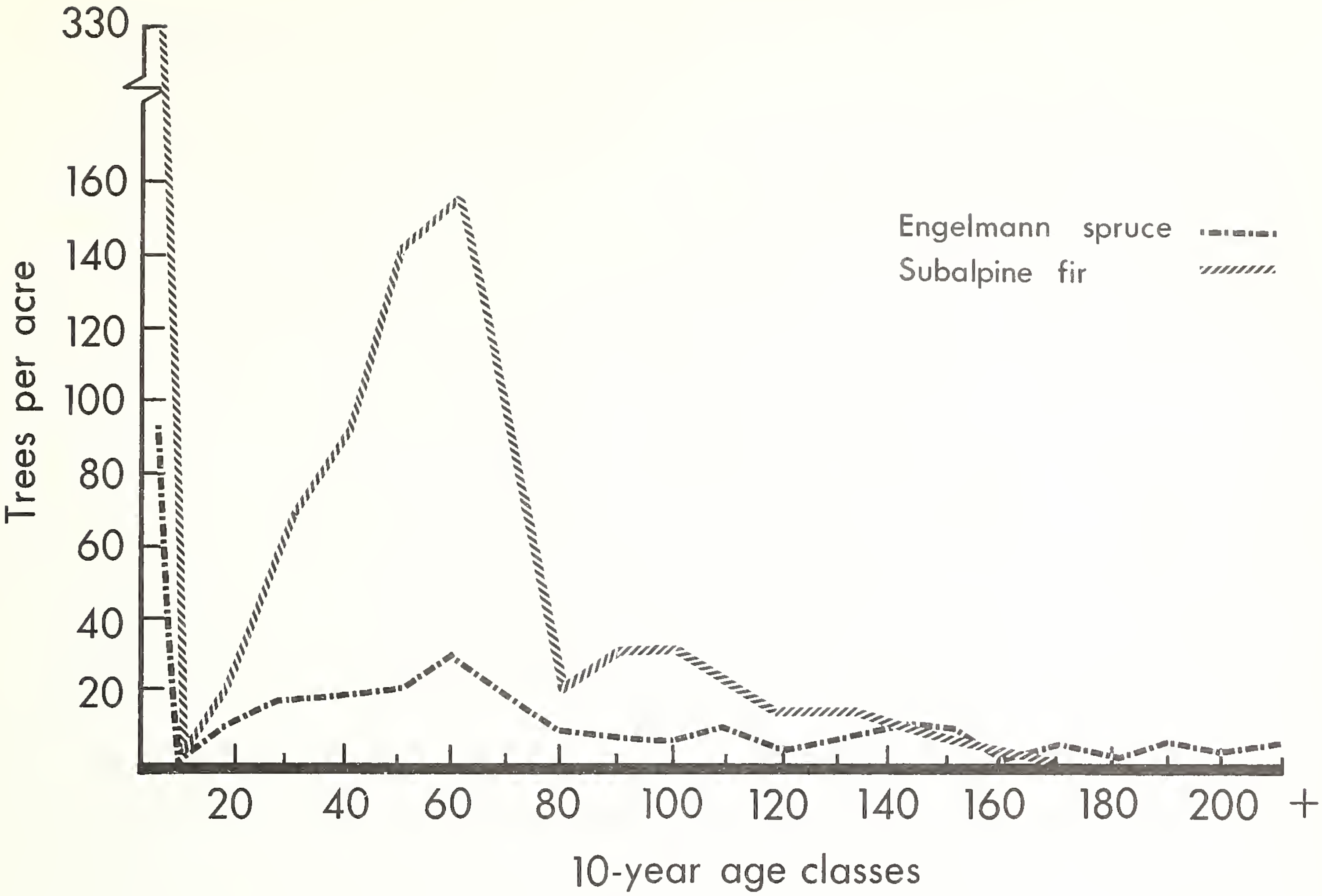



*Figure 6.--Deer Hollow stand age-class distribution, 1972.*

## Species Composition

Species composition varied between the study locations (table 1). At the Clayton stand, tree density was higher and species more evenly distributed. Deer Hollow tree density was dominated by subalpine fir, accounting for almost 70 percent of the stocking. Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, and limber pine, *Pinus flexilus* (James), were also present in the Deer Hollow stand as widely scattered individuals.

Heart rot and root-rotting fungi were prevalent (table 1). *Fomes annosus* (Pfister 1972), for subalpine fir, and *Fomes igivarius* (Frykman 1958), for aspen, appear to be the major fungi. Most aspens more than 8 inches d.b.h. had heart rot. Spruce was less affected by these rotting fungi.

Spruce and subalpine fir had large numbers of seedlings, with subalpine fir exceeding spruce about 2 to 1 in the small sizes. Subalpine fir gained this numerical advantage by being able to reproduce on duff-covered seedbeds (Roe and others 1970). It also gained additional stocking through its unique ability to reproduce by layering. Subalpine fir mats, up to 20 feet across, were occasionally observed on the study areas. The layered stems grew slowly, requiring up to 100 years to reach 1-inch diameter near the ground line.

Table 1.--*Species composition and percentage of heart rot of two stands in the spruce-fir type of southern Utah*

| Tree species | Trees/acre | Species composition | Heart rot[1] |
|---|---|---|---|
| | | - - - - - - - *Percent* - - - - - - - | |
| CLAYTON STAND | | | |
| Engelmann spruce | 746 | 40 | 11 |
| Subalpine fir | 975 | 52 | 10 |
| Aspen | 139 | 8 | 86 |
| Total | 1,860 | 100 | |
| DEER HOLLOW | | | |
| Engelmann spruce | 308 | 20 | 5 |
| Subalpine fir | 1,042 | 69 | 8 |
| Aspen | 147 | 10 | 94 |
| Limber pine | 8 | <1 | 25 |
| Douglas-fir | 1 | <1 | 0 |
| Total | 1,506 | 100 | |

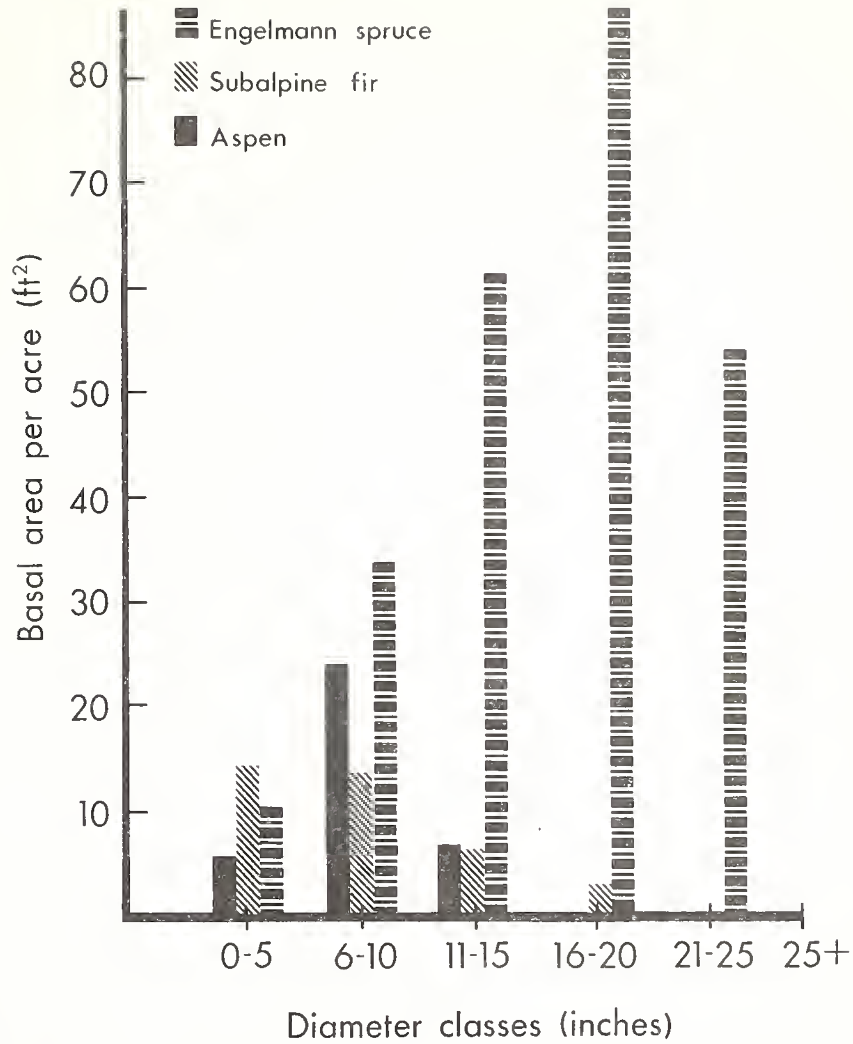
[1]Heart rot percentage by species is based on the number of trees 1 inch and larger in diameter.

Of total basal area, spruce accounted for 78 percent at the Clayton stand and, 62 percent at the Deer Hollow stand (fig. 7 and 8). Larger diameters and a greater proportion of large stems accounted for the higher spruce basal areas. Spruce trees at the Clayton stand averaged 0.33 square foot of basal area, while the larger spruce diameters at the Deer Hollow stand averaged 0.59 square foot basal area.

Subalpine fir accounted for 11 and 31 percent of the basal areas at the Clayton and Deer Hollow stands, respectively. Subalpine fir was characterized by high density but relatively low basal area at both stands due to the large proportion of medium and small diameters. Subalpine fir at the Clayton stand averaged 0.04 square foot basal area, while the larger diameters at the Deer Hollow stand averaged 0.09 square foot basal area.

Aspen accounted for the remaining 11- and 7-percent basal area at the Clayton and Deer Hollow stands, respectively. Variability of aspen basal area was high due to the clonal nature of the species.

Figure 7.--Clayton stand basal area by diameter classes.



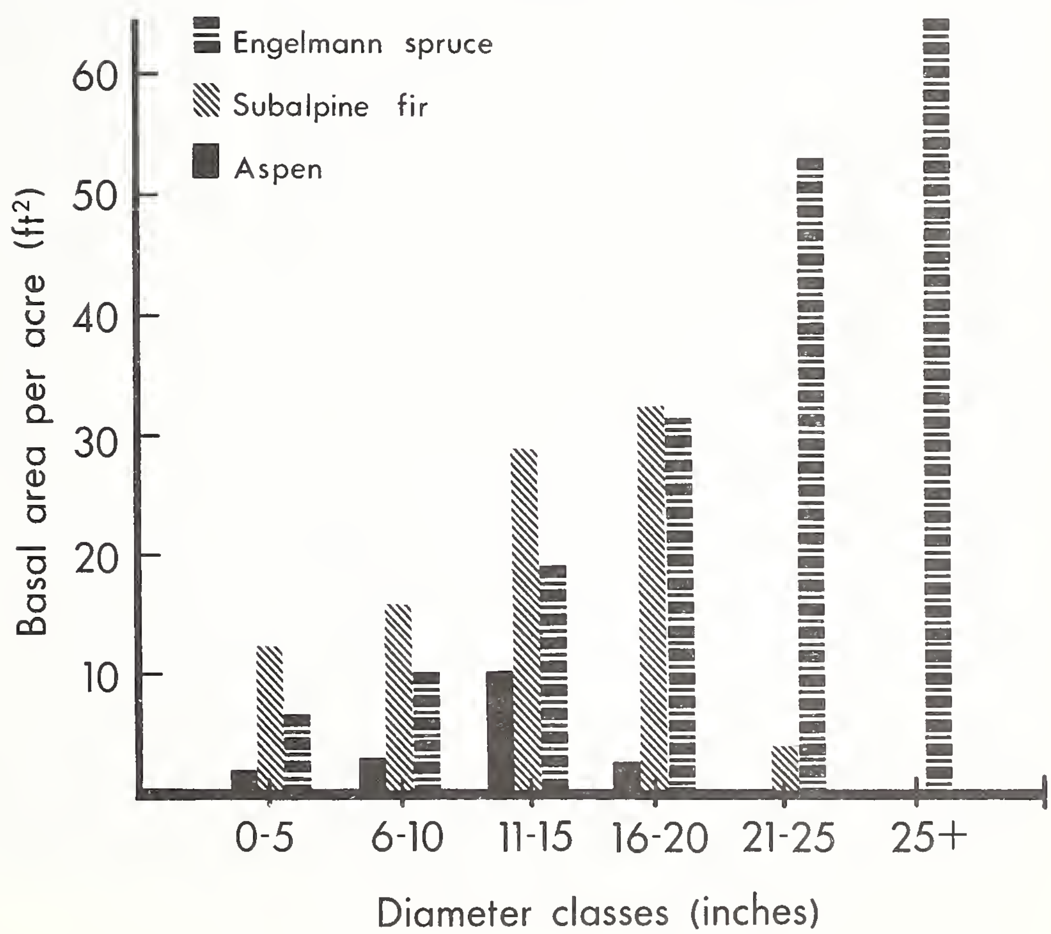




Figure 8.--Deer Hollow stand basal area by diameter classes.

## Stand Successional Status

The Clayton stand appears to be at equilibrium with its environment, representing the climax vegetation. Subalpine fir and Engelmann spruce are coclimax species in the association. Spruce maintains its position in the overstory with an average longevity of 2 to 1 over the subalpine fir, reproducing in abundant quantities on favorable microsites, i.e., partial shade and mineral soil. Subalpine fir reproduces under the spruce canopy on a variety of seedbeds, but does not overtake the dominant crown position of the spruce. In other words, a subalpine fir may complete its entire life cycle under the shade of an older larger spruce.

Aspen, a seral species, becomes established as small clones after severe disturbances of the overstory. Examples of such disturbances are local epidemic insect populations, severe windthrow areas, and small localized lightning fires. Uneven-aged conifer reproduction occurs beneath the aspen, eventually succeeding it. Thus, the aspen clones serve as "nurse crops."

The role of aspen in the successional development of the Deer Hollow stand appears similar to the Clayton stand in that uneven-aged conifer reproduction was observed under the aspen clones (fig. 9). Larger aspen clones, up to 30 acres, and the "wavelike" nature of the subalpine fir reproduction under the clonal canopy suggest the possibility of a widespread disturbance at Deer Hollow approximately 60 years ago. This disturbance apparently altered the conifer canopy and allowed abundant aspen sprouting. The widespread disturbance to the conifer canopy could have been caused by bark beetles, windthrow, or fire. Windthrow and fire are good possibilities because the Deer Hollow stand is near the rim of the plateau where remnants of burned bark could be seen on surviving old-growth Douglas-fir trees.

*Figure 9.--Uneven-aged conifer reproduction under the protection of an even-aged aspen clone.*

# SILVICULTURAL IMPLICATIONS

Silvicultural practices in the high-elevation spruce-fir forests must be based on a sound ecological framework. Two important ecological factors stressed in this paper are the uneven-aged structure and the projected vegetation changes over time. In addition, studies of successional trends (Pfister 1972) and regeneration[3] of these *same* spruce-fir forests complement results from this study and, combined, provide the basis for the following recommendations:

1. An uneven-aged silvicultural system should be tested in similar southern Utah spruce-fir forests. Specifically, light group or individual tree selection methods appear to mimic the natural dynamic condition affecting these forests, and we recommend that they be examined under regular management situations. These methods should provide favorable microsites for conifer seedlings and prevent severe seedling mortality from frost, desiccation, and soil movement. However, all traditional timber harvesting methods, including our recommendation, have some flaws when applied to these severe sites. Heavy partial cuts can result in severe windthrow, resulting in epidemic bark-beetle populations. Careful logging to minimize bole and root damage, together with high utilization standards and adequate slash treatment, would have to be undertaken to reduce bark-beetle brooding sites.

2. If even-aged management is the goal of the land manager, the shelterwood system appears most compatible with these stand conditions and should be tested. The logging precautions stated in recommendation 1 may be required to keep bark-beetle populations in check. Pfister (1973) stated that clearcutting with planting may be an appropriate silvicultural method in the *Abies lasiocarpa/Berberis repens* habitat type. We agree that this even-aged method is feasible *if* extreme care is taken in the actual planting and site modification is provided to reduce the environmental extremes found at the soil surface.[3] More study should be given to the use of aspen clones as nurse crops in the regeneration of clearcuts.

The authors feel that the recommendations given are the most appropriate for timber management in these high-elevation spruce-fir forests. Participation of other forest disciplines, i.e., entomology, range, and wildlife, must be included in all phases of management planning and operations if the land management objectives are to be achieved.

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[3]Op. cit.

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Analyses of age-class distribution of three species within two uneven-aged stands on adjacent plateaus showed that Engelmann spruce, the primary species, was predominantly all-aged, subalpine fir was uneven-aged, and quaking aspen was even-aged. This age-class structure suggests the need for testing an uneven-aged silvicultural system in the management of these forests.

OXFORD: 228.6:182.2:221.
KEYWORDS: age-class structure, Engelmann spruce (Picea engelmannii (Parry)), subalpine fir (Abies lasiocarpa (Hook.) Nutt.), stand succession, silvicultural systems.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

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AMERICAN REVOLUTION BICENTENNIAL
1776-1976

GROWING FROM '76
U.S. FORESTRY CENTENNIAL